Suspended particulate matter on the Louisiana shelf: Concentrations, composition and transport pathways

J.H. Trefry, R.P. Trocine and S. Metz
Florida Institute of Technology, Melbourne, Florida 32901

T.A. Nelsen
NOAA/AOML/OCD, Miami, Florida 33149

N. Hawley
NOAA/GLERL, Ann Arbor, Michigan 48105

Abstract

The concentrations, composition and transport pathways of suspended particulate matter and particulate organic carbon (POC) have a direct bearing on the development and persistence of shelf hypoxia as well as on the global cycling of carbon. More than 120 CTD-transmissometer profiles and >400 particle samples were collected from the Mississippi River and adjacent Gulf of Mexico on cruises during July-August 1990 and February 1991. River-flow is a dominant factor in controlling particle distributions; however, time-series data show that tides and weather fronts can greatly influence concentrations and movement of suspended matter. Results from chemical analyses show that concentrations of POC range from >80 μmol/L (>1 mg/L) at near-river locations to <0.8 μmol/L (<0.01 mg/L) in some deep offshore waters. The organic fraction of the suspended matter increases from <5 percent of the total mass near the river mouth to >90 percent along the shelf at about 10 km from the river. The C/N molar ratio in suspended particles from throughout the shelf is near uniform at 6. Plumes of particle-rich water at outer shelf depths of about 100 m, along with transport in near-bottom nepheloid layers, carry a POC burden that can be traced tens of kilometers offshore.

Suspended particles are a landmark feature of the Mississippi River and its seaward plume. These particles are important to both the production and transport of biogenic carbon and nitrogen because:

1. Particulate carbon and nitrogen, either brought in by the river or fixed in shelf waters, may be transported to other locations on the shelf or offshore to the continental slope.
2. The concentrations of suspended particulate matter (SPM) may limit the amount of available light and thereby reduce the amount of photosynthesis in a given area of the Mississippi Delta.
3. Decomposition of particulate organic carbon plays a role in the creation and persistence of hypoxia.

Suspended particles in the Mississippi River typically contain 1 to 2 percent organic carbon and 0.15 to 0.3 percent nitrogen with a C/N ratio commonly ranging from 6 to 9 (Trefry and Presley, 1976; and this study). Thus, the terrigenous load of particulate organic carbon (POC) for the Mississippi River is on the order of 2 million metric tons per year, about the same as that for dissolved organic carbon (DOC). Terrestrial inputs of POC and particulate nitrogen (PN) are, of course, greatly augmented by production of marine POC and PN along the Louisiana shelf.

Concentrations of SPM in river plumes can inhibit primary productivity by reducing light penetration and are sometimes modeled as inversely related to plankton biomass. Some field data suggest that an SPM value of about 10 mg/L is a threshold for primary production. For example, Demaster *et al.* (1986) showed that diatom uptake of silica in the Amazon River plume begins when levels of SPM fall below 10 to 20 mg/L, with most of the silica uptake occurring at SPM values of <10 mg/L. The Amazon study also showed that changes in river flow and plume dynamics can displace the critical SPM boundary by as much as 20 km or more on a daily to seasonal scale. The massive and dynamic plume of the Mississippi River can have a similar effect.

The SPM component of the NECOP Program was designed to determine the concentration and composition of suspended particles on the Louisiana shelf as a function of depth and location as well as to determine the importance of bottom resuspension and lateral transport to movement of organic and inorganic particles. Within this context, our study has focused on identifying the spatial (3-D) and temporal distribution of SPM, POC and PN along the Louisiana shelf and how this relates to dissolved oxygen distribution, apparent oxygen utilization (AOU) and the onset and persistence of hypoxia. Particulate carbon and nitrogen serve as tracers of biogenic material and particulate aluminum, iron and manganese trace detrital particles and resuspended sediment. Knowledge of the transport and fate of biogenic carbon has a direct bearing on our understanding of the development and persistence of shelf hypoxia as well as on the global cycling of carbon.

Methods

To achieve our objectives, more than 50 stations were occupied on each of the two NECOP cruises, NECOP I (July-August 1990) and NECOP II (February

1991). The stations shown in Fig. 1 were sampled using a rosette equipped with a Neil Brown CTD system, transmissometers and Teflon-lined Go-Flo water sample bottles. As a conceptual framework, the sample sites were grouped into the following five subgroups: (1) a circum-Delta arc; (2) a river mouth to shelf edge transect, referred to as the Mississippi Canyon transect; (3) a transect from the head of the Mississippi Canyon to the area of chronic hypoxia; (4) the hypoxia area; and (5) offshore stations. In addition to the sample sites described above, two anchor stations (AN-1 and AN-2) were occupied on both cruises for approximately 36 hours at each site per cruise. Anchor Site 1 was chosen to characterize temporal variations in the concentrations and composition of SPM within hundreds of meters of the river mouth at Southwest Pass. Anchor Site 2 was situated within an area of chronic hypoxia as established by the ongoing monitoring of Rabalais and co-workers. At each anchor station, a current meter record was obtained in the near-bottom flow field. The CTD and transmissometer data provided detailed snapshots of the distribution of SPM throughout the delta, outer shelf and slope.

To complement the data obtained by CTD/transmissometer, we collected more than 400 samples of SPM on both glass fiber and polycarbonate filters during the July-August 1990 and February 1991 cruises for chemical analysis and scanning electron microscopy. The water samples were collected with 10-L Go-Flo bottles or by pumping. All filtrations were carried out immediately after collection in a clean van aboard ship. Concentrations of suspended matter along with particulate Al, Fe, Si, Ca, Mn, Pb and Cd were determined using samples collected on 0.4 µm polycarbonate filters. Analysis was by flame or flameless atomic absorption spectrophotometry following complete digestion with $HF\text{-}HNO_3$ in a sealed tube. Concentrations of POC and PN were determined using samples collected on glass fiber filters and analyzed with a Carlo Erba NA1500 CNS system.

Results and Discussion

Initial results from both NECOP cruises will be presented in this report. The distribution of SPM will be considered first and then a picture of chemical composition will be developed. The goal of this paper is to provide preliminary results of the spatial and temporal changes in the concentrations and composition of the suspended particles in the Mississippi River, on the Louisiana shelf and in offshore waters.

Seasonal differences in the concentrations of suspended matter in the Mississippi River are demonstrated by the SPM values at Head of Passes for July-August 1990 (NECOP I) of 44 mg/L versus 180 mg/L for February 1991 (NECOP II). A sharp decrease in SPM values to <10 percent of river levels occurred within 5 to 10 km of the river mouth at Southwest Pass on both cruises. A further decrease in SPM to <3 mg/L occurred by 15 to 30 km from the river in July and 30 to 80 km in February. These seasonal variations in the concentrations of suspended matter near the river mouth contribute to shifts in the location of areas of maximum productivity.

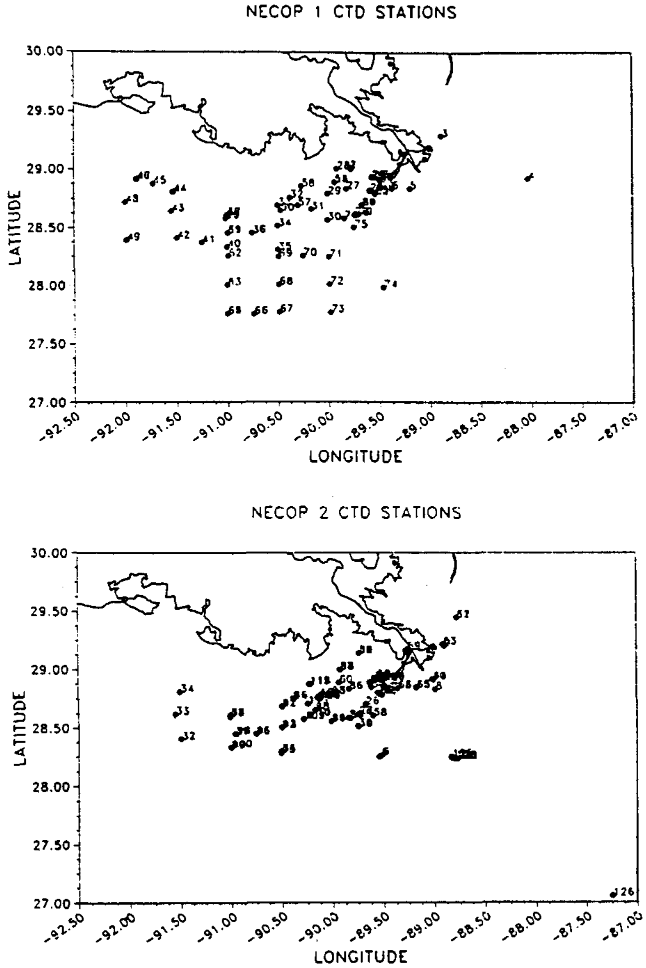

Fig. 1. Maps showing station locations for CTD, transmissometer and water samples during NECOP I (July-August 1990) and NECOP II (Leg 1, February 1991).

Examples of short-term (hours to days) shifts in the concentrations of suspended particles were observed at the anchor stations. Anchor stations 1 (28°54.4'N, 89°29.8'W) and 2 (29°08.3'N, 89°44.1'W) were located adjacent to the mouth of Southwest Pass and within the core of chronic hypoxia, respectively. One noteworthy example of rapid changes in SPM occurred at AN-1 during February 1991. Over a 30-hour period, surface salinity varied from <5 parts per thousand (ppt) to 18 ppt with SPM concentrations varying indirectly with salinity. This observation is common in this area and is related to tidal effects. Within the near-bottom nepheloid layer salinity remained at about 36 ppt; however, sizeable variations in SPM values were observed. These changes in concentrations of SPM in near-bottom water can be directly related to passage of a short-duration weather front over the site. As the front passed, bottom current speeds increased from about 5 cm/sec (about 0.1 knot) to a peak of about 35 cm/sec (0.7 knot) with an order-of-magnitude increase in the concentrations of SPM (Fig. 2). The amount of

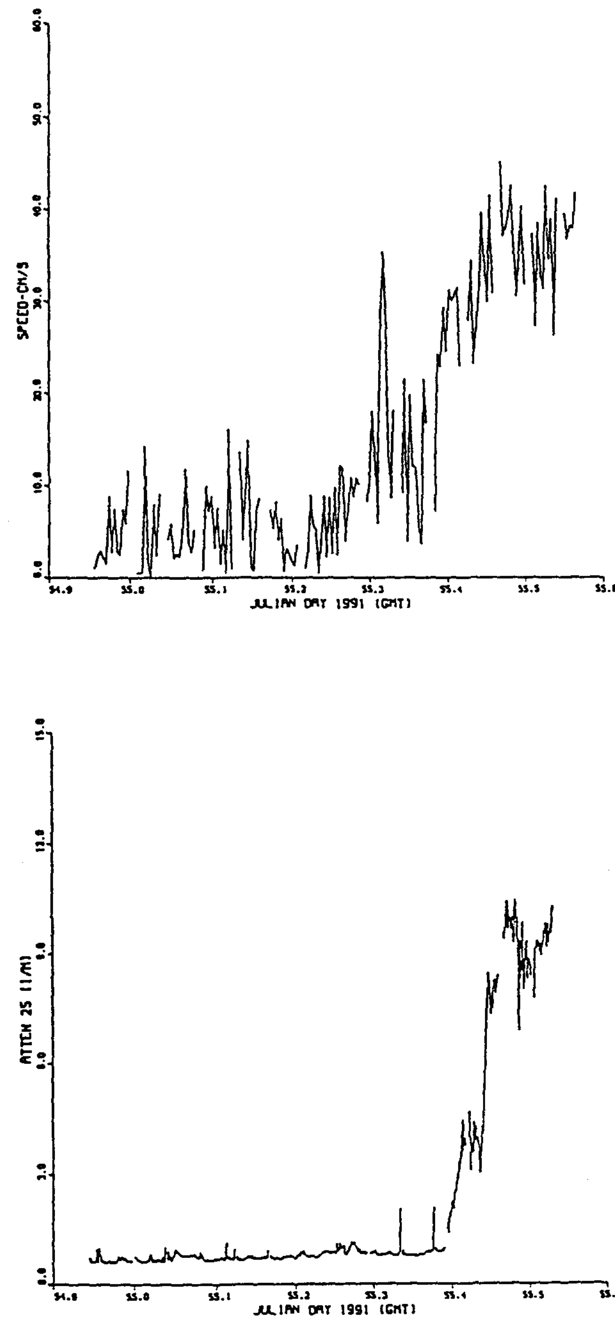

Fig. 2. Graphs showing (a) light attenuation for 25-cm path length transmissometer versus time and (b) current speed versus time for Feb. 24, 1991, at Anchor Station 1.

particulate matter as well as POC and PN transport along the shelf thus increased greatly. These changes in particle loading can have a direct effect on oxygen depletion as pulses of increased POC and PN move toward the area of chronic hypoxia. Detailed calculations of transport as well as temporal and spatial variations in concentrations of SPM and dissolved oxygen are ongoing.

From a chemical perspective, concentrations of particulate organic carbon and particulate nitrogen also show spatial and temporal changes. The POC value for the Mississippi River was 110 µmol/L (1.3 mg/L) for July-August and 220 µmol/L (2.6 mg/L) for February. Even though the Summer particles contained more organic carbon (3.1 percent) than the Winter particles (1.6 percent), the river carried twice as much POC during the February period.

Further delineation of the spatial and temporal trends in POC can be seen in Fig. 3, which shows POC values for Anchor Stations 1 and 2 for the Summer and Winter cruises. The POC values (Fig. 3) have been divided into terrestrial and marine components using both δC-13 and the POC/Al ratio. Values for the δC-13 of terrestrial POC in the river are about -25 per mil, increasing to -20 per mil in marine POC (Eadie, person. comm.). The POC/Al ratio at Head of Passes varies seasonally and was 0.44 for NECOP I and 0.20 for NECOP II. The POC/Al ratio decreases to as low as 0.01 when the terrigenous material settles out of the plume and production of marine POC begins. By using end-member values for both the δC-13 and the POC/Al ratio, we can estimate the fraction of terrestrial and marine organic matter that comprise a given POC sample. Agreement between the two approaches is good in most instances; however, when questions arise the δC-13 values were considered more reliable.

At Anchor Station 1, the terrestrial POC is almost 50 µmol/L in February 1991 relative to 20 µmol/L in July 1990 (Fig. 3). This difference is in response to the increased particle load of the river during the NECOP II cruise. The difference in marine POC is equally dramatic; however, the trend is reversed with the higher marine component occurring in Summer (Fig. 3). Yet, the greater runoff was in Winter. Although somewhat preliminary, the observed differences at Anchor Station 1 show the combined effects of concentrations of SPM (light penetration), nutrient loading (river flow), and temperature on the levels of terrestrial and marine POC in the near-river-mouth area.

At Anchor Station 2, some 30 km away, the terrestrial POC values (Fig. 3) are markedly lower than at Anchor Station 1 during both cruises with <5 µmol/L in mid-water samples during the July 1990 period. Values for marine POC are similar for both the Summer and Winter cruises at Anchor Station 2.

A primary focus of the NECOP program is on the development of seasonal hypoxia. One means to assess trends in oxygen distribution is by the apparent oxygen utilization (AOU). Actual values for AOU at Anchor Station 1 in February are similar to those for July (Fig. 4); however, the Summer trend of increasing AOU with depth is clearer. The AOU values of 100 µmol/L represent utilization of about 60 percent of the dissolved oxygen. During both time periods, values for AOU increase between AN-1 and AN-2.

The trends for POC and AOU observed between Anchor Stations 1 and 2 can be followed farther west into an area of more intense seasonal hypoxia. At Station 26 (28°36.4'N, 91°00.8'W) during NECOP II, POC values were 6 to 26 µmol/L, essentially all marine and similar to concentrations observed at Anchor Station 2 (Fig. 3). Levels of AOU at Station 26 of 100 µmol/

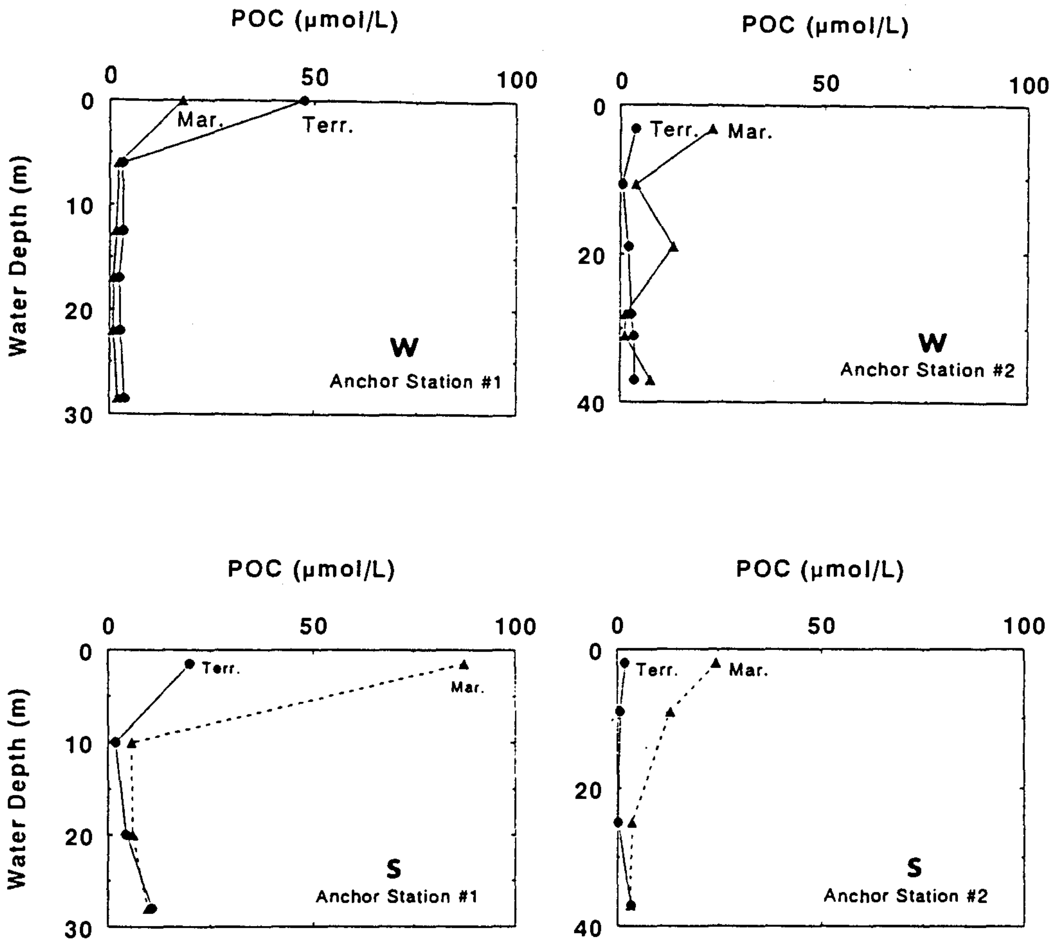

Fig. 3. Graphs showing values for particulate organic carbon (POC) versus depth for Anchor Stations 1 and 2 during NECOP I (S=Summer, July-August 1990) and NECOP II (W=Winter, February 1991).

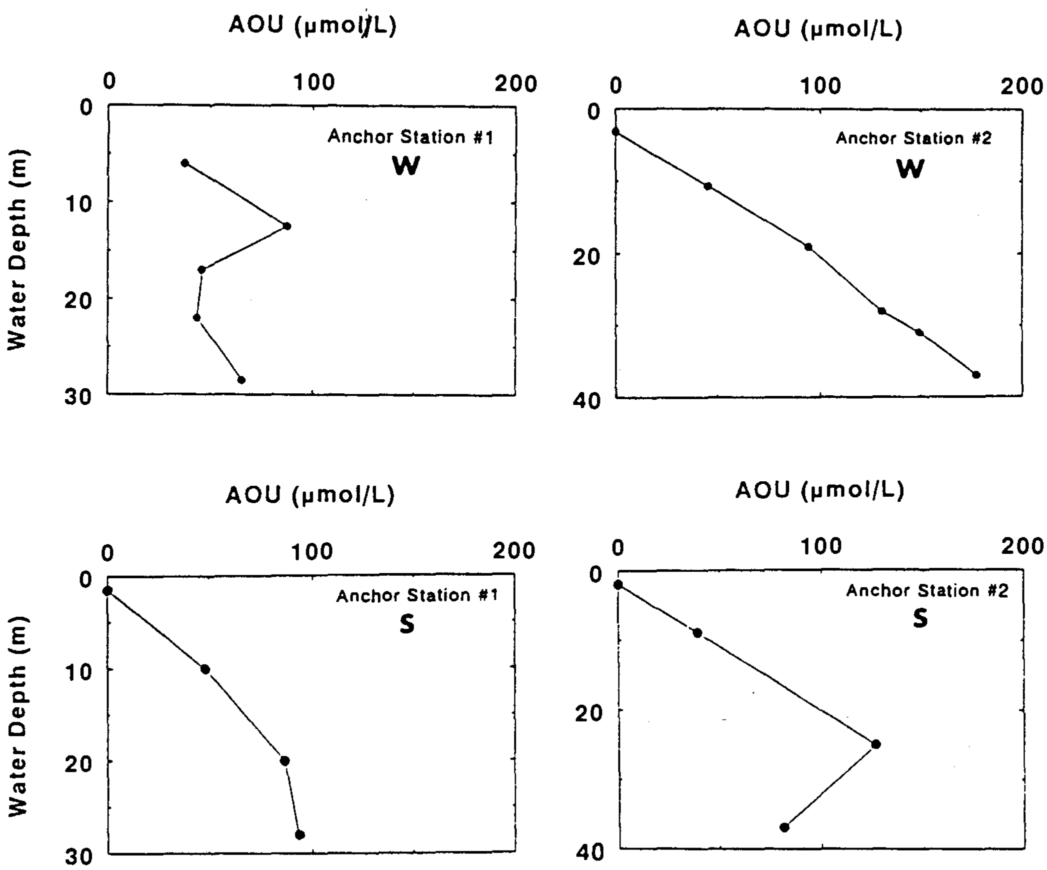

Fig. 4. Graphs showing values for apparent oxygen utilization (AOU) versus depth for Anchor Stations 1 and 2 during NECOP I (S=Summer, July-August 1990) and NECOP II (W=Winter, February 1991).

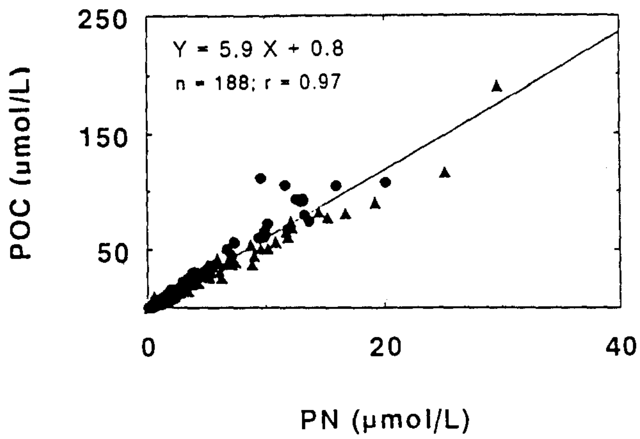

Fig. 5. Graph showing concentrations for particulate organic carbon (POC) versus particulate nitrogen (PN) for samples from both NECOP I and II cruises.

L were somewhat lower than AN-2 during this time of year. In contrast to the February 1991 observations, POC values during July-August in the western area around 91°W were 6 to 50 µmol/L, levels of AOU approached 200 µmol/L and dissolved oxygen values were as low as 0.4 mg/L. As our data processing continues, we are evaluating the seasonal and spatial trends of POC and AOU along and across the Louisiana shelf.

In addition to the POC data, we have carried out chemical analyses for particulate nitrogen, aluminum, silicon, calcium, manganese and selected trace elements. Our analyses for both NECOP cruises are complete and data interpretation is underway. Within the data set, we find that the C/N molar ratio for the entire NECOP I and II suspended matter data sets averages 5.9 (Fig. 5). This ratio is close to the classic Redfield ratio. Values for particulate manganese are elevated to as high as 5 percent in near-bottom water, especially during the Summer, as a result of release of dissolved Mn from the sediment interstitial water and subsequent oxidation of manganese oxides in the overlying water. Particulate Pb values (expressed as µg/g) decrease offshore as Pb-bearing river particles settle out of the water column. Particulate Cd values (expressed as µg/g) tend to increase offshore in response to increased biological uptake.

Conclusions

More than 120 CTD-transmissometer profiles and >400 particle samples were collected from the Mississippi River and adjacent Gulf of Mexico during July-August 1990 and February 1991 cruises. In addition to river-flow dependent variations in particle distributions, time-series data show the importance of tides and weather fronts on the concentrations of suspended matter. Results from chemical analyses show that concentrations of POC range from >80µmol/L (>1 mg/L) at near-river locations to <0.8 µmol/L (<0.01 mg/l) in some deep offshore waters. The organic fraction of the suspended matter increases from <5 percent of the total mass near the river mouth to >90 percent along the shelf at about 10 km from the river. The C/N molar ratio in suspended particles from throughout the shelf is near uniform at 6. Plumes of particle-rich water at outer shelf depths of about 100 m and in near-bottom nepheloid layers carry a POC burden that can be traced tens of kilometers offshore.

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